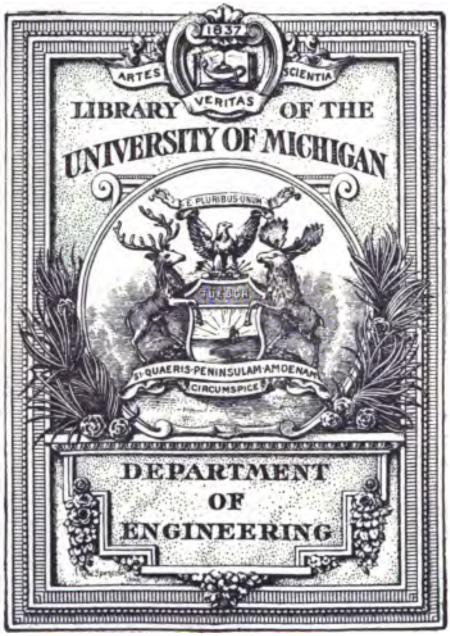
AMERICAN STANDARD SPECIFICATIONS FOR STEEL

BY

ALBERT LADD COLBY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REVIEW AND TEXT

OF THE

American Standard Specifications for Steel,

ADOPTED IN AUGUST, 1901,
BY THE

AMERICAN SECTION OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

BY

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—ALSO—

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Second Edition, Rewritten and Containing the Revised Text of the Standard Specifications.

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1902.

STANDARD TEST SPECIMEN OF TWO-INCH GAUGED LENGTH.

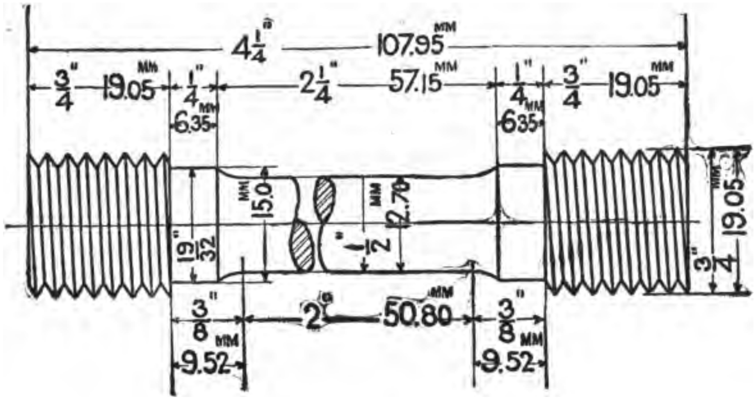

FIGURE 1.

STANDARD TEST SPECIMEN OF EIGHT-INCH GAUGED LENGTH.

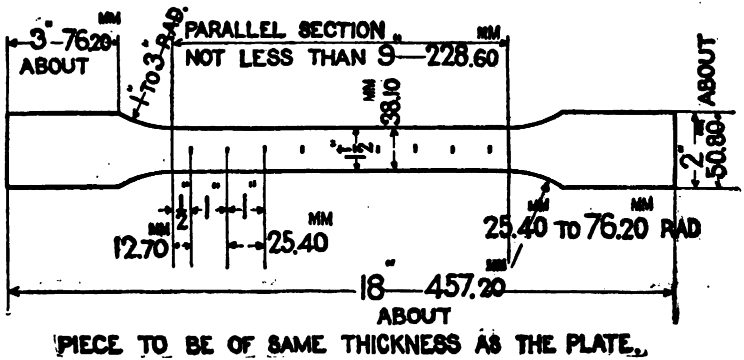

FIGURE II.

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Revised Text of the American Standard Specifications for Steel, adopted by the American Section of the International Association for Testing Materials, August 10, 1901.

INTRODUCTION.

The first successful effort in America to standardize specifications for steel was made in August, 1895, by the Association of American Steel Manufacturers, a technical organization formed to discuss matters pertaining to the manufacture and use of steel. These specifications the Steel Association revised on July 17th, 1896, and October 23rd, 1896. They included specifications for structural steel for buildings, bridges and ships, special open-hearth plate and rivet steel, and structural cast iron.

Although these specifications were at first criticized and referred to by the technical press and by some engineers as "manufacturers' standards," they nevertheless grew in favor among consumers when it was found that just as good steel was furnished, as when using specifications containing many additional tests and requirements unnecessary in the present state of the art of making steel. The customer also soon appreciated that these *standard* specifications secured closer competition and more prompt deliveries.

The formation of the American Section of the International Association for Testing Materials on June 16th, 1898, gave an excellent opportunity for engineers, consumers, and manufacturers to come together with a view of framing American standard specifications covering all the various kinds of iron and steel, for among the twenty-two problems which were presented by the parent Association, problem No. 1 asked the American Section to cooperate in establishing "international rules and spe-

cifications for testing and inspecting iron and steel."

Under authorization of the Executive Committee of the American Section, the American Branch of Committee No. 1 was increased to thirty-four members, half of whom were engineers, professors in technical schools, consumers of steel, or delegates from scientific societies, and half representatives from the leading American manufacturers of the various kinds of iron and steel.

This Committee held frequent meetings beginning March 9th, 1899. Its sub-committees collected and tabulated the requirements of existing American specifications which were used as a basis in framing the ten proposed American standard specifications endorsed as representative of the best American practice by a letter ballot of the Committee and published in May, 1900. These proposed standards have been discussed by some of the leading American technical societies and journals, as well as by the International Congress on Testing Materials of Construction, held in Paris, in July, 1900, and by The Iron and Steel Institute, in September, 1900.

The American Section of the International Association for Testing Materials, at its third Annual Meeting held in October, 1900, after a detailed discussion, referred the ten proposed standard specifications back to their Committee No. 1. The Committee, after frequent meetings, again presented them with some modifications at the fourth Annual Meeting of the American Section, June 29th, 1901. They were then adopted subject to a letter ballot of the full membership of the Section. This letter ballot, canvassed on August 10th, 1901, en-

dorsed the action of the American Section in adopting as American standards the specifications as revised. The full revised text of these specifications is given in the Appendix, pages 57–103.

In drawing up the standard specifications the Committee were conservative, and included in the main, only such requirements as have been proved in practice to be of value or essential in determining whether or not the material is suited for the purpose intended. Contradictory and obscure clauses were eliminated, and tests of very doubtful value as a measure of the material when in service as well as those unnecessary in the present state of the art, were as far as possible omitted. The specifications were adopted as representing the American practice of to-day. They were adopted as American standards, subject to change, and will be reconsidered by the American Section of I. A. T. M. whenever requirements of service become more severe, better methods of testing are developed, or future improvements in manufacture render modifications necessary or advisable.

At the Congress of the International Association for Testing Materials held at Buda Pesth, in September, 1901, *national* standard specifications were submitted by the American, German, and French branches of Committee No. 1. A resolution recommended by the Council, was passed by the Congress calling upon the Chairman of International Committee No. 1 to report at the next Congress to be held in St. Petersburg, in 1903, on the expediency of adopting international specifications, and, if possible, to prepare a set of proposed *international* specifications for iron and steel.

The first edition of this review was presented by the writer at the International Congress on Testing Materials of Construction, held in Paris in July, 1900. It included the text of the proposed standard specifications drafted by the committee in May, 1900. This second edition has been condensed and rewritten, and the appendix contains the revised text of the American Standard Specifications as adopted by the American Section of the International Association for Testing Materials on August 10th, 1901.

It is hoped that the publication of the text of these specifications, in this convenient form, with a critical review by a member of the committee, giving the *reasons* which governed the committee in its decisions, will aid in the adoption of these specifications by large consumers, and by American engineers in their professional work. They are not intended to cover every specific purpose, but they will serve for the majority of uses to which steel is applied, and can be modified to suit particular requirements without departing materially from the standard form and practice recommended. After a practical trial some changes will doubtless be recommended and adopted by the American Section of the International Association for Testing Materials.

If honored at home it will materially aid in securing their acceptance abroad by the other sections of the International Association, as a basis of international standards, a result bringing benefit to the foreign consumer, as well as practical returns to the American engineer and the American manufacturer.

ALBERT LADD COLBY.

South Bethlehem, Pa.,
February, 1902.

GENERAL REVIEW OF THE REQUIREMENTS SPECIFIED, WITH THE REASONS WHICH GOVERNED THE COMMITTEE IN ITS DECISIONS.

The American Branch of Committee No. 1, in drafting the specifications which were adopted in August, 1901, by the American Section of the International Association for Testing Materials, as American standards, selected the seven following headings under which the requirements and tests of each specification were classified:

1. Process of Manufacture.
2. Chemical Properties.
3. Physical Properties.
4. Test Pieces and Methods of Testing.
5. Finish and Variation in Weight.
6. Branding.
7. Inspection.

These headings will be reviewed in turn, the similar requirements in each specification compared, and the reasons given which governed the Committee in its decisions.

PROCESS OF MANUFACTURE.

The first paragraph in each of the nine standard specifications gives the process or processes by which the steel shall be made. For convenience they are given in tabular form.

TABLE I.

Specifications for	Open-hearth process.	Bessemer process.	Crucible process.
1. Steel castings	Open-hearth	Bessemer	Crucible
2. Steel axles	Open-hearth	——	——
3. Steel forgings	Open-hearth	Bessemer	Crucible
4. Steel tires	Open-hearth	——	Crucible
5. Steel rails	Open-hearth	Bessemer	——
6. Steel splice bars	Open-hearth	Bessemer	——
7. Structural steel for buildings	Open-hearth	Bessemer	——
8. Structural steel for bridges and ships . .	Open-hearth	——	——
9. Open-hearth boiler plate and rivet steel .	Open-hearth	——	——

Details of Processes Should Not Be Specified.— Restrictions as to the *details* of the processes of manufacture were purposely and very properly omitted by the Committee, because, in general, it is outside of the province of the engineer to specify details of metallurgical processes when he is afforded by the manufacturer every reasonable facility to test the finished material. The specification for steel rails is an exception, as certain details, appearing as a matter of form in most rail specifications, were included. (See § 1, page 74.)

If an engineer prefers acid rather than basic open-hearth steel, he can so specify. He may also demand a certain percentage of top discard. If he desires the finished material annealed, it is also proper for him to so define the process of annealing, that it shall not include a slow cooling from the initial temperature of casting, or rolling, or forging, although it is better for him to specify high elongation and contraction of area than to attempt to dictate all the details of the annealing process.

Although omitted in the standard specifications, such details in the processes as above indicated, could properly be inserted to cover special cases. It is, however, plainly outside the engineer's jurisdiction to specify, as is sometimes done, the raw materials to be used, the method of decarbonization, the size and weight of the ingot, the method of casting, the character of workmen to be employed, etc., etc. Moreover, *conscientious* inspection, under specifications governing the details of nearly every step in the manufacture, is *utterly impossible* within the cost of inspection allowed by the engineer or contractor. In eight foreign rail specifications the manufacturer is limited to the use of "the best English or Spanish hematite pig iron and charcoal spiegeleisen." This unnecessary requirement, of course, cannot be complied with in any American rail mill, and if strictly interpreted would seriously limit English competition.

During the discussion of the proposed American standard specifications at the Paris Congress, the French, German, Belgian, and English united in objecting to placing any restrictions whatever upon the manufacturer as to the process to be used in making the steel.

CHEMICAL PROPERTIES.

Chemical Requirements. — Table II gives the chemical requirements of the nine specifications under discussion. Where tensile strength is specified, limits in carbon were purposely omitted, except in the case of splice bars, where a carbon limit was included for the reason that the specified physical properties are seldom actually called for.

TABLE II.—REQUIRED LIMITS IN THE

	Specification for
Steel castings.	Ordinary castings . . . . Tested castings . . . .
Steel axles	Car, engine truck, and tender truck . . . . Driving wheel (carbon steel) . . . . Driving wheel (nickel steel) . . . .
Steel forgings.	Of soft or low carbon steel . . . . Of carbon steel, not annealed . . . . Of carbon steel, oil-tempered or annealed . Of nickel steel, oil-tempered or annealed .
Steel tires.	
Structural steel for buildings, including rivets	
Structural steel for bridges and ships, including rivets.	Of acid open-hearth steel . . . . Of basic open-hearth steel . . . .
Open-hearth boiler plate and rivet steel	Flange or boiler steel { of acid O. H. steel . Flange or boiler steel { of basic O. H. steel . Fire box steeel . . . { of acid O. H. steel . Fire box steeel . . . { of basic O. H. Steel . Extra soft steel . . . .
Steel rails of weights per yard specified.	50 lbs. to 59 + lbs . . . . 60 " " 69 + " . . . . 70 " " 79 + " . . . . 80 " " 89 + " . . . . 90 " " 100 " . . . .
Steel splice bars.	

CHEMICAL COMPOSITION OF STEEL.

Phos. not over	Sulphur not over	Carbon.	Mangan.	Silicon.	Nickel.
0.08		not over 0.40			
0.05	0.05				
0.06	0.06				
0.06	0.06				
0.04	0.04				3.00–4.00
0.10	0.10				
0.06	0.06				
0.04	0.04				
0.04	0.04				3.00–4.00
0.05	0.05		not over 0.80	not under 0.20	
0.10					
0.08	0.06				
0.06	0.06				
0.06	0.05		0.30–0.60		
0.04	0.05		0.30–0.60		
0.04	0.04		0.30–0.50		
0.03	0.04		0.30–0.50		
0.04	0.04		0.30–0.50		
0.10		0.35–0.45	0.70–1.00	not over 0.20	
0.10		0.38–0.48	0.70–1.00	not over 0.20	
0.10		0.40–0.50	0.75–1.05	not over 0.20	
0.10		0.43–0.53	0.80–1.10	not over 0.20	
0.10		0.45–0.55	0.80–1.10	not over 0.20	
0.10		not over 0.15	0.30–0.60		

Limits in manganese were included in the case of tires, boiler plate and rivet steel, splice bars and rails, and silicon only in the case of tires and rails. Phosphorus was very properly specified in all the different classes included in the nine steel specifications, and sulphur in all but rail steel, splice bars and structural steel for buildings. No limit in copper was specified, as it has been conclusively proved[1] that it exercises no deleterious influence even when present in greater proportions than found in the steel made in certain localities in the United States, partly dependent on ores carrying small quantities of this ingredient.

Carbon Not Specified.—The omission of carbon, when tensile strength is specified, is in accordance with the latest and best views on this subject. Instances might easily be cited from existing specifications where the tensile strength specified could not be met if the required limits in carbon, and in some cases manganese and silicon, were adhered to in the selection of the steel. Furthermore, to meet a specified tensile strength, a different carbon steel must generally be selected if made by the basic open-hearth, than if the steel has been made by the acid open-hearth process.

Where the physical properties desired are clearly and properly specified, the chemistry of the steel, other than prescribing the limits of the injurious

[1] H. H. Campbell's "Manufacture and Properties of Structural Steel," New York, 1886, pp. 274, 275. "Copper in Steel," by Albert Ladd Colby. *The Iron Age*, Vol. lxiv, November 30, 1899, pp. 1–7. "The Influence of Copper in Steel Rails and Plates," by J. E. Stead and John Evans. *J. Iron and Steel Institute*, Vol. I, 1901, pp. 89–100.

impurities, phosphorus and sulphur, may in the present state of the art of making steel be safely left to the manufacturer. Nor should a steel be rejected by an inspector, when meeting all the physical properties specified, because it happens to contain 0.005 per cent. over the required limit of sulphur or phosphorus.

PHYSICAL PROPERTIES.

The actual physical properties specified will not be compared here in tabular form, because they will be referred to in detail in the discussion of each of the nine specifications. (See pages 32–56.) The present discussion will be confined to the *reasons* for selecting the particular physical properties of steel which were specified by the Committee.

Tensile Strength, Yield Point, Elastic Limit.—Tensile strength is specified in order to insure the necessary strength in the material. The elastic limit is, however, the true index of resistance to working stresses. In material uniformly heated before rolling, a large number of tests have proved that the elastic limit practically never falls below 50 per cent. of the tensile strength. As its accurate determination is an impossibility in rapid commercial testing, the tensile strength is relied upon to indicate the elastic limit, with which information the stresses which may be successfully carried can be safely computed.

The yield point as determined in commercial testing was also specified because it furnishes a desirable check on the accuracy of the assumption that the elastic limit of the material under consideration is at least one-half of the tensile strength.

With high-grade steel forgings, subjecting to rapidly alternating stresses, the elastic limit was specified instead of the yield point, and provision made for its accurate determination.

Elongation.—In the large majority of commercial steels, elongation is a safe index of ductility. In the present state of the art it is a safe check, where only minimum tensile strength is required, against the use of a steel too high in carbon or other hardening elements for the purpose intended. The ease with which the determination can be made on rolled material makes it valuable and desirable in the commercial testing of large output, where rapidity as well as accuracy of testing is demanded.

Contraction of Area.—The percentage of contraction of area was included in the requirements for castings, axles, and forgings where the tensile strength is determined on a *turned* test specimen. It was omitted from the specification for tires, where a turned specimen is also used, because it was considered an unnecessary requirement in testing the high carbon steel used in this case, as the tires are very seldom annealed.

The value of this determination as an index of the quality of steel is fully appreciated by those who have made a comparative study of the micro-structure, and the accompanying physical properties as determined on turned specimens. The uniformly fine-grained micro-structure, only attained when a proper heat treatment has given to the steel the best physical qualities, is invariably accompanied by the highest percentage of contraction of area obtainable with any given class of steel.

Bending Tests.—The cold-bending test is a valuable indication of the structure of the metal, and in this respect bears a close relation to the contraction of area. The two are indications of the same quality in the steel, namely, its capacity for cold flow. A steel having a high contraction of area will always stand severe cold bending, and, conversely, a steel capable of severe cold bending will always show high contraction of area. This makes the cold-bending test particularly valuable, as an indication of the structure of the metal, in cases where there is any difficulty in obtaining a true and ready measure of the contraction of area. It is a safeguard against brittleness produced by too high finishing temperatures.

The quench-bending test required for open-hearth boiler plate and rivet steel, insures the absence of any excess of carbon or other hardening element.

Drop Tests.—The specifications for axles, tires, and rails call for a drop test, and in the specification for steel castings it states that a test to destruction may be substituted for a tensile test in the case of small or unimportant castings, with a view to showing that the castings are ductile and free from injurious defects. None of the other specifications include a drop test.

Drop tests were included in the specifications for axles, tires, and rails, as it was fully appreciated by the Committee that material which will be submitted to shocks when in actual use should be tested by impact. In each case the drop test adopted is in accordance with general American practice, which, after a number of years' experi-

ence, has been found to give very satisfactory results.

Homogeneity Test.—This test is confined to fire-box steel. Its object is to show the uniformity of the metal, that is, freedom from closed or partially welded blowholes, pipe, or slag. A sample taken from a broken tensile specimen shall not show any single defective flaw or slag streak more than a quarter-inch long in any of the three fractures obtained by carrying out the test as described in the specification, page 96.

Percussive Test.—This test is only specified for large steel castings. It consists in suspending and hammering the casting at numerous places. The test is made to locate any cracks, flaws, defects, or weakness in casting.

TEST PIECES AND METHODS OF TESTING.

Standard Test Specimens.—When testing sheared plates and structural shapes, the practice is now so general in America of measuring the elongation in eight inches (8″), that the Committee at once adopted the standard test specimen shown in Figure II for the specifications for structural steel for buildings, structural steel for bridges and ships, open-hearth boiler plate and rivet steel, and splice bars. They provided that for the materials other than sheared plates included in these four specifications, the test specimen may be that shown in Figure II, or it may be planed or turned parallel throughout its entire length, but that in all cases, where possible, two opposite sides of the test specimen shall be the rolled surfaces ; also that rivet

rounds and small rolled bars shall be tested of full size as rolled. In the specification for splice bars it is not specified whether the test specimen shall be planed parallel or of the shape shown in Figure II. Owing to the shape of the section of splice bars the parallel specimen can be more readily obtained. In all these necessary variations from the shape of specimen shown in Figure II, however, the same gauged length of eight inches (8″) was specified.

In the present day of large products of structural and plate steel, the preparation of the many test specimens, without a delay in shipment of finished material, demands the adoption of a standard sized specimen which can be readily prepared in groups, by special machines, from the coupons from plates of varying thicknesses. The ability to compare the physical properties of different makes of such a wide variety of steel, made possible by the use of the standard test specimen, also shows the wisdom of the Committee's action. As eight inches (8″)= 203.2 millimeters, our results can be safely compared with tests made on the Continent where the standard gauged length is 200 millimeters.

Although some of the existing American specifications for steel castings, steel forgings, steel axles, and steel tires, tabulated by the Committee, specified an elongation in eight inches (8″), the Committee after thorough investigation did not adopt a turned specimen of an eight inch (8″) gauged length, but recommended, as a standard for testing these four materials, the two inch (2″) test specimen of one-half inch (1/2″) diameter, shown in Figure I, and they specified correspondingly higher

percentages in elongation. The following reasons governed this decision :

The shorter specimen has the great advantage of enabling the customer to determine the character of the material at places in a complicated casting or forging where there is not space enough for a longer specimen, as between the webs of crank shafts. In the case of steel tires the shorter specimen is greatly preferable, for when cut from the rim of the tire used for the drop test, the longer specimen can very seldom be obtained unless the tire is heated and straightened, an operation which at once destroys its value as a representative test of the finished tires of the melt.

When using this test specimen of a gauged length of four diameters for the commercial testing of all steel forgings, including steel axles, a much shorter prolongation of the forging is required for a longitudinal specimen than for a test specimen of 8-inch gauged length. The shorter specimen therefore requires the manufacturer to consign much less good metal to scrap, an item of considerable importance to the customer in the case of forgings of large diameters. Furthermore, less time and labor is expended in cutting out and machining the shorter test specimen. At a given cost a much better idea of the quality of the metal can therefore be obtained, for several short specimens can be taken at different positions in an important casting or forging at the same cost for preparation as one long specimen.

Finally, the physical properties called for in the specifications for steel castings, axles, forgings, and tires can be accurately and readily determined when

using the standard test specimen recommended; for in cases where elastic limit is specified instead of yield point, an apparatus reading to the one ten-thousandth of an inch (0.0001″) can be easily attached and readings readily made. The determination of the tensile strength is not materially affected by the length of the specimen. The percentage of contraction of area and the quality of the fracture, both very important factors in determining the quality of the metal, are shown with equal accuracy and distinctness with the shorter specimen as with one of greater length. The higher percentages of elongation obtained on two inches (2″) are compensated for by having correspondingly higher requirements in the specifications. In proof of the above assertions, the writer submitted to the Committee Table III, showing a series of comparative tests made with much care in the 300,000 pound Emery Hydraulic Testing Machine used by the Bethlehem Steel Company. In each case the tests were threaded on both ends and the elastic limit made with an electric micrometer. The table shows close practical agreement save in the increased elongation on the shorter specimen. As above noted the Committee, in adopting the two inch (2″) test bar, specified correspondingly higher elongations.

TABLE III.

COMPARISON OF THE PHYSICAL PROPERTIES OF STEEL FORGINGS DETERMINED OF TWO-INCH (2″) AND OF TEN-INCH (10″) GAUGED LENGTH.

	Tensile strength. lbs. per sq. inch.		Elastic Limit. lbs. per sq. inch.		Extension in 2″ and 10″.		Contraction of area.	
	2″ Bar.	10″ Bar.	2″ Bar.	10″ Bar.	2″ Bar. Per cent.	10″ Bar. Per cent.	2″ Bar. Per cent.	10″ Bar. Per cent.
Engine Forgings	86,580	88,800	49,910	50,220	28.00	17.00	58.00	51.04
Crank Web	81,490	79,820	49,910	46,210	30.00	22.70	58.00	51.70
Link Beam Pin	93,200	90,390	60,090	59,320	27.00	19.60	59.96	56.83
Crank Pin	90,650	88,980	60,090	62,120	28.00	20.00	62.53	60.91
Engine Forging	91,670	89,740	59,080	62,370	28.50	18.00	60.55	55.63
Crank Web	84,030	82,860	53,980	51,940	27.00	24.30	51.55	56.44
Crank Web	89,120	86,440	53,980	53,200	27.00	21.30	54.83	53.06
Pin	94,600	94,330	60,330	62,880	26.00	19.80	52.73	51.28
Crosshead Pins and Collars	89,630	87,820	55,000	52,440	27.00	19.80	49.29	46.56
Main Shaft and Eccentric Rod	89,990	91,530	52,150	56,520	25.50	20.00	46.48	49.30
Engine Forgings	91,670	89,880	63,150	62,500	26.00	21.00	49.57	50.72
Engine Forgings	92,180	91,020	62,130	61,980	26.50	19.80	47.57	44.65
Piston Rod	90,140	85,290	51,950	52,950	27.00	19.00	58.00	55.77

Number and Location of Tensile Specimens.—In specifying the number and location of the tensile specimens, the Committee were governed partly by the best current practice, and always by the character and relative importance of the material to be tested. Each specification includes definite instructions on these two points.

Annealing of Tensile Specimens. — When the material is annealed or given any special heat treatment, it is specified that the tensile specimen shall receive the same treatment before testing. In all cases where practicable the tensile specimen shall be cut from the material after it has received its final heat treatment.

Methods for Tensile Tests. — The Committee, after considerable discussion, did not prescribe methods for tensile tests other than to distinguish between yield point and elastic iimit. The commercial methods used in this country for determining the tensile strength, elongation and contraction of area compare very favorably, and in some cases excel those used abroad, and any inaccuracies which may be due to rapid testing are, save in special cases, of no practical importance.[1]

Test Specimens for Bending.—Where bending tests are required the dimensions of test specimens for bending are given in the specifications, as well

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[1] See "Comparison of the Actual Every-day Practice of American Steel Works in Testing Steel with the Methods of Testing Adopted by the French Commission and the International Conventions," forming a chapter of a paper by the writer, read before the Paris Congress on Testing Materials, June, 1900.

as their number, their location, and proper provision is made for testing annealed material. Data presented to the Committee led them to specify that the bending could be made "either by pressure or by blows."

Methods for Drop Tests.—The specifications follow current American practice in specifying the details of the methods used in making the required drop test on axles, tires, rails and castings.

Method of Homogeneity Test.—The Committee wisely copied the method described by the Pennsylvania Railroad, who originated this test on fire-box steel.

Method for Percussive Test.—This test of large steel castings consists simply in suspending and hammering the casting at numerous places to test its soundness.

Samples for Chemical Analysis.—The mere fact that limits in chemical composition are included in a specification, presupposes that common sense will be used in selecting the sample for analysis. Almost any material included in the nine specifications covered in this review, could be rejected if samples were purposely taken from the unavoidably segregated portions of the finished material.

This fact partly justifies the stand taken by foreign critics that the chemical requirements should be entirely omitted, when these proposed American specifications were offered, in 1900, to the Paris Congress and to the Iron and Steel Institute as a basis for international standards.

The Committee made an honest effort to harmon-

ize interests in framing the paragraphs found in each of the nine specifications defining the location of the drillings or turnings to be taken to determine whether or not the material conforms to the prescribed chemical requirements. A large tonnage of satisfactory material is being furnished, on specifications giving the methods of sampling recommended by the Committee. If an engineer, desiring further protection against segregation, specifies more rigid sampling, he must expect to pay more for the finished material, as an increased top discard will be necessary in its manufacture.

Methods for Chemical Analysis.—All suggestions as to methods for chemical analysis were purposely omitted from the specifications under discussion. Entire uniformity in the details of the various analytical methods used in steel works laboratories will probably never be realized, nor is it a necessity in obtaining accurate chemical analyses.

Great credit should be given to the steel works chemist for the success which has attended his earnest efforts to meet the urgent demands made on him for rapid accurate analyses, for he has thereby very materially assisted the steel-maker in securing and maintaining uniformity in his product.

FINISH.

Such a wide variety of finished material is covered in the nine steel specifications under discussion, that a summary of the clauses contained under this heading is impossible. In each case the requirements were drawn so that only material with a workmanlike finish and freedom from injurious imperfections shall be accepted. In the

specifications for rails the question of finish is treated under the subdivisions "Section," "Weight," "Length," "Drilling," and "Finish." Second quality, or No. 2 rails, are also defined.

PERMISSIBLE VARIATIONS IN WEIGHT.

The variation in weight permissible in rolling plates was very properly included by the Committee in the specifications for structural steel for buildings, structural steel for bridges and ships, and open-hearth boiler plate and rivet steel. The overweight is caused by the unavoidable wear of the plate rolls, producing a plate slightly thicker in the central part than on the edges. A prescribed standard of excellence in this regard places all manufacturers on equal footing, and requires them to keep their plate rolls in good condition. The allowances were based on the assumption that one cubic inch of steel weighs 0.2833 pound, and provision was made for plates ordered by weight, and also when ordered to gauge. The prescribed variations are the same in each of the three specifications.

With rails a variation of one-half per cent. (1/2 %) for an entire order is allowed. With splice bars a variation in weight of more than two and one-half per cent. (2 1/2 %) from that specified is a sufficient cause for rejection.

BRANDING.

The marking of finished material is now in general use. It permits the identification and date of manufacture of material which has given exceptionally good or long service, or which has

failed in service, and is thus a protection and an advertisement for the reputable manufacturer. A review under this heading of the nine steel specifications shows that, in all cases but castings and forgings,[1] every finished piece must be marked, except that small pieces may be shipped in bundles securely wired together, with the melt or blow number on a metal tag attached. In the case of rails, besides stamping the blow number of each rail, the name of maker, the month and year of manufacture, must be rolled in raised letters on the side of the web of each rail. In splice bars the name of maker and the year of manufacture must be rolled in raised letters on each side of the splice bars. In axles, besides the melt number, the initials of the maker must be stamped on each axle ; and in tires, the maker's brand and number must be stamped on each finished tire.

INSPECTION.

Each specification makes ample provision to insure the inspector all facilities necessary for a thorough inspection of the material, and specifies that all tests and inspections shall be made at the place of manufacture prior to shipment.

[1] Some makers always mark each casting and forging, whether or not it is so specified.

REVIEW OF EACH OF THE NINE AMERICAN STANDARD SPECIFICATIONS FOR STEEL, WITH THE REASONS WHICH GOVERNED THE COMMITTEE IN ITS DECISIONS.

SPECIFICATION FOR STEEL CASTINGS.

In drawing up this specification, the Committee provided for the four classes of steel castings which make up the majority of the tonnage manufactured.

First, "*Ordinary*" castings which are not subjected to any specified physical tests. These castings are usually made of open-hearth, but sometimes of Bessemer steel, and are seldom, if ever, annealed. The Committee specified a maximum limit of 0.40 per cent. carbon and 0.08 per cent. phosphorus for this ordinary grade of castings.

Second, "*Tested*" castings, those submitted to certain physical tests before acceptance. For these a maximum of 0.05 per cent. phosphorus and 0.05 per cent. sulphur was specified, they were subdivided into three classes, "soft," "medium," and "hard," and the minimum physical qualities given in section 4, pages 58–59, were specified.

It is unnecessary to put a maximum limit on the tensile strength if the elongation specified for the minimum limit is present. The yield point required is 45 per cent. of the tensile strength. As

usually determined it will run 50 per cent. A somewhat higher elongation is specified for each of the three classes than given in most specifications now in use, and the contraction of area is also specified although very seldom demanded in existing specifications.

A bending test, although not usually specified, was added by the Committee for soft and medium castings, as ductility is an important requisite in a steel casting especially for the moving parts of machinery.

This increase in requirements, while favoring the customer, recognizes the improvements made of late years in the manufacture of steel castings.

Although all steel castings should be annealed, such a large majority of them are not so treated, that a standard specification intended to cover a majority of the tonnage made, could not do otherwise than leave this important matter for adjustment in individual cases.

In inserting the class called "hard" castings with a minimum tensile strength of 85,000 pounds, an elongation of 15 per cent. and a contraction of area of 20 per cent., the Committee recognized the growing demand for a quality of castings used for grinding or crushing machinery and to some extent as a substitute for ordinary unannealed steel forgings. By special methods of heat treatment, both with and without the introduction of nickel and other special elements, steel castings are now furnished, meeting much higher physical qualities than above quoted.

The paragraphs on test specimens, sample for

analysis, finish, etc., show that the Committee has protected the customer on all essential points.

SPECIFICATION FOR STEEL AXLES.

In the first paragraph of this specification the Committee confines the manufacturer to open-hearth steel for axles. Bessemer steel, as usually made, is not of sufficient uniformity in quality, and is commercially out of the question with the specified maximum limit of 0.06 per cent. in phosphorus.

In specifying the chemistry of axles, the Committee followed their policy of omitting carbon when definite physical tests were specified—in this case a limit to the deflection caused by the first blow of the drop test. Existing specifications show a wide range in specified carbon from 0.20 up to 0.50 per cent. The Pennsylvania Railroad specification, and the Master Car Builders' recommended practice, is 0.35–0.50 per cent. carbon. As axles are now largely made of basic open-hearth steel of comparatively low phosphorus, sulphur, manganese, and silicon, and as the axle blooms are much more carefully heated, forged, and cooled than heretofore, the higher range in carbon is perfectly safe and perhaps in the future the tendency will be to aim for 0.50 per cent. carbon and recommend a slight reduction in the deflection. The carbon should be as high as experience shows is safe, with a properly designed axle. The Pennsylvania Railroad adopted their axle specifications in January, 1896. In 5 1/2 years up to June 1st, 1901, 307,000 axles had been purchased and only 3 returned; and these failures were due to internal

flaws and not from any fault in the composition of the steel.

Limits in manganese and silicon were purposely omitted. The maximum of 0.06 per cent. phosphorus and 0.06 per cent. sulphur is fair to both manufacturer and consumer.

The physical test for car, engine truck, and tender truck axles consists of a drop or impact test on one axle from each heat. A limit is placed on the deflection under the first blow in order to rule out too soft or too low carbon steel; see section 5, page 63. The drop test is simpler than a tensile test, and preferable in this case, and it tests one whole axle out of each lot.

The Committee wisely adopted as a standard the machine and method of making this drop test originated by the Pennsylvania Railroad in 1896 and adopted in 1899 by the Master Car Builders' Association as its recommended practice. The Committee added a clause to the requirements, stating that the report of the test shall state the atmospheric temperature at the time the test is made. The actual influence of the ordinary variations of temperature, 32° F. to 100° F., is a matter of conjecture, but it is definitely known that such temperatures as 0° F. diminish the resistance of steel to sudden shock; but on the actual extent of its influence on the deflection of axles, no experimental data was at hand. The Committee's recommendation that the temperature be made a matter of record during testing, seems, therefore, reasonable for the present.

Two grades of *driving-wheel* axles are specified, differing in both chemical and physical require-

ments, as shown in sections 2 and 4, pages 62–63, both tests being taken midway between center and outside of one axle from each melt.

The minimum physical qualities guaranteed in the nickel steel driving axles are considerably higher than those of simple carbon steel axles; the higher elastic limit should appeal to those who desire the best possible material for a part of the modern heavy locomotive subjected in service to such severe alternating stresses as the driving-wheel axle.

The specification provides for all classes of axles, that the chemical analysis can be made on a sample taken *midway* between the center and outside of one axle from each melt. This differs from the M. C. B. specification which for no *logical* reason specifies that the center of the 5/8-inch hole drilled longitudinally to obtain the sample for analysis, shall be 40 per cent. from the center. This location grew out of a compromise suggested in a dispute in which the railroad chemist claimed that he had the right to take his sample drillings from the center of the axle. A point midway between the center and surface is fair to both parties. A location nearer the center simply gives higher percentages of metalloids than contained in the portion of the axle submitted to the greatest fiber stresses in service, and is no surer protection than the Committee's suggestion, against segregated axles due to insufficient top discard.

The Committee specifies that the axles shall be branded "at the places marked on the print or indicated by the inspector." It would have been well if they had called attention to the M. C. B's.

axle design recommended in 1899, in which small sections on both sides of the center are left rough turned as a sort of collar on which the marking shall be placed; stamping on the finished machined body of the axle is undesirable, as it is liable to establish local weakness.

It is a pity that the proper *design* of axles was outside of the Committee's jurisdiction. Small wheel fits, sharp fillets, and a taper between hub and center of axles not based on uniform fiber stress, have caused many "failures in detail" unjustly attributed to the steel of which the axle was made.

SPECIFICATION FOR STEEL FORGINGS.

The large variety of steel forgings furnished by the trade were divided by the Committee into four classes:

I. Forgings of Soft or Low Carbon Steel.—For these ordinary forgings, a limit of 0.10 per cent. phosphorus and sulphur was specified which permits the use of Bessemer steel. To provide for cases when these low priced forgings are subject to test, certain minimum physical qualities were specified, which are to apply to all solid or hollow forgings of this class, not over 10″ in any diameter or thickness of section.

II. Forgings of Carbon Steel, Not Annealed.—The limit given of 0.06 per cent. phosphorus and sulphur prevents the use of Bessemer steel, as far as American practice is concerned. The physical qualities specified necessitate the selection of a higher carbon steel than used for soft steel forgings. A wide

variety of forgings are comprised in this class, the distinctive feature of which is that the finished forging is *not* submitted to any heat treatment. Only comparatively low percentages of elongation and contraction of area could, therefore, be specified.

III. Forgings of Carbon Steel, Oil-Tempered or Annealed.—For the higher grade of steel forgings included in this class, the phosphorus and sulphur were very properly limited to 0.04 per cent. so as to insure the selection of a high quality of open-hearth or crucible steel. The term "carbon steel" is used to distinguish the material from nickel steel or steel containing any other special element. This class differs from the preceding one, in that the finished forging is either annealed or oil-tempered. Higher physical qualities are specified when the forgings have received the latter treatment. In each case the minimum physical properties required, vary with the diameters or thickness of section of the solid and hollow forgings.

As the increased cost of forgings of this class is only justified by their satisfactory service under severe or sudden strains, and as this service is measured by the *true* elastic limit of the steel, the Committee made the distinction in the specification of steel forgings, between "yield point" and "elastic limit," specified the latter for the high grade of forgings included in classes III and IV, and described the methods by which each shall be determined.

IV. Forgings of Nickel Steel, Oil-Tempered or Annealed.—The same phosphorus and sulphur limit of 0.04 per cent. is specified as for Class III. The

range of 3 to 4 per cent. of nickel was selected as the majority of the nickel steel forgings contain about 3.25 to 3.50 per cent. nickel. While materially increasing the elastic limit the nickel also adds to the toughness of the steel. This is shown by comparing the minimum physical properties specified for this class of forgings with the forgings of Class III of the same diameters and heat treatment. In each case the nickel steel is required to meet a higher elastic limit, and at the same time, higher elongation and contraction of area.

The increased cost of nickel steel forgings, over the carbon steel forgings included in Class III, is justified where the forging will be subjected to high alternating stresses, or liable to sudden and severe shocks. However, a carefully melted homogeneous nickel steel should be used and great care must be exercised in the forgings, and especially in the final heat treatment. Where severe service is demanded and yet lightness in construction is a requisite, no material yet offered is equal to a hollow nickel steel forging carefully oil-tempered.

Bending Tests.—The specification for steel forgings includes a bending test for each of the four classes of forgings.

Test Specimens.—Careful instructions were included by the Committee, governing the number and location of tensile test and bending test specimens, as well as the drillings for chemical analysis. The two-inch tensile specimen was adopted as a standard for testing steel forgings, for the reasons given on pages 23–26.

SPECIFICATION FOR STEEL TIRES.

Such a small proportion of the tonnage of tires furnished to American railroads are subject to any specification, that in drafting an "American" standard specification, the Committee was governed largely by the foreign specifications met by American tire makers, when furnishing tires for locomotives built in this country for export.

The specification adopted, includes a minimum tensile strength and elongation for passenger engines, freight engines, and car wheels, and switching engines. In each case limits in manganese, silicon, phosphorus, and sulphur are specified.

A drop test is included, giving a formula for tires of different diameters and thickness, by which the minimum deflection before fracture can be calculated. The tire is placed vertically under the drop, in a running position, and the required deflection, before fracture, must be obtained by successive blows of a ton weight falling from gradually increasing heights. In the writer's opinion the comparative stiffness of tires could be more accurately measured by a specified minimum deflection, after a single blow made under uniform conditions.

The following table compares the minimum deflections for tires of different diameters and thickness, calculated on the basis of the formula given in the standard specification, and on two other formulae.

TABLE IV.

DROP TEST FOR STEEL TIRES.

Internal diameter and thickness of tire.	Deflection (d) according to formulae.		
	$d = \frac{D^2}{40\,T^2 + 2D}$.	$d = D^2 \div 40\,T^2$.	$d = \frac{D^2}{160\,T}$.
24″ × 3″	1.41″	1.60″	1.20″
24″ × 2½″	1.93″	2.31″	1.44″
24″ × 2″	2.76″	3.60″	1.80″
36″ × 3″	3.00″	3.60″	2.70″
36″ × 2½″	4.02″	5.18″	3.24″
40″ × 3½″	2.81″	3.28″	2.86″
40″ × 3″	3.64″	4.45″	3.33″
40″ × 2½″	4.86″	6.40″	4.00″
60″ × 3¾″	5.27″	6.40″	6.00″
60″ × 3½″	5.93″	7.38″	6.43″
60″ × 3″	7.50″	10.00″	7.50″
77″ × 3¾″	8.30″	10.55″	9.90″
77″ × 3½″	9.23″	12.15″	10.60″
77″ × 3″	11.55″	16.50″	12.33″

SPECIFICATION FOR STEEL RAILS.

This important specification[1] fairly represents

[1] The United States contains over 40 per cent. of the entire railway mileage of the world. The official report of the production of steel rails in the United States during recent years was as follows:

	Gross tons.
1894	1,017,098
1895	1,300,325
1896	1,117,663
1897	1,645,020
1898	1,977,922
1899	2,271,108
1900	2,384,987

American practice at the time of its adoption. None of the specifications were adopted as American standards for all time, and as traffic conditions are increasing in severity, and owing also to recent improvements in finishing rails at lower temperatures, none is more likely to require some early modification than this one.

A review of the many specifications and discussions on rails published in the past ten years cannot but impress one with the fact that often general and far-reaching conclusions have been drawn from insufficient and unreliable data. It is to be hoped that the two rail Committees[1] appointed since these standard specifications were drawn, will make no recommendations not based on exhaustive practical research.

The writer will review the Committee's standard specification; touch upon possible future modifications, and in view of the important tonnage of American rails made for export,[2] will refer to some of the requirements of foreign rail specifications.

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[1] Rail Committee of the American Railway Engineering and Maintenance-of-Way Association. Preliminary report, March, 1901.

Rail Committee of the American Society of Civil Engineers authorized by letter ballot in July, 1901.

[2] The following official statistics show the tonnage and value of steel rails exported from America in recent years:

	Gross tons.	Value.
1894	12,229	$ 323,880
1895	8,807	222,661
1896	72,503	1,712,716
1897	142,808	2,949,901
1898	291,038	5,787,384
1899	271,272	6,122,382
1900	356,245	10,895,416

Process of Manufacture.—The standard specification permits the use of either Bessemer or open-hearth steel. The general clause specifying that the process of manufacture and testing shall be in accordance with the best current practice, was inserted to keep the specification up to date, and also in lieu of burdening it with many clauses occurring in rail specifications, specifying details in manufacture which but reflect the practice of every modern American rail mill. However the important points of keeping ingots in a vertical position, not rolling any "bled" ingots, and requiring sufficient top discard to insure sound rails, were specially mentioned in the standard specification. A "bled" ingot is one from the center of which liquid steel has escaped. The committee might have added a clause specifying that chilled heats shall not be used, and that top poured and badly poured ingots shall not be used for making first quality rails.

Chemical Properties.—The specification follows western requirements, and limits the phosphorus to 0.10 per cent. Silicon is limited to 0.20 per cent. Sulphur is not specified nor is it necessary to do so; a range of carbon and manganese is given, varying with the weight of the rail section. Many specifications fix a lower maximum for phosphorus, some placing it at 0.085 per cent. and others, especially foreign specifications, at 0.06 per cent. As to silicon, specifications vary between 0.06 to 0.25 per cent. A number limit the sulphur, which really only interests the maker, to 0.06 per cent., and the manganese called for by customers varies between the wide ranges of 0.40 to 1.20 per cent.

In the writer's opinion the demand for *special* chemistry, especially when obtainable only at an increased cost, will rapidly disappear when the longer life of rails finished at lower temperatures has been proved by service. Reasonable practical limits in chemical composition, including carbon, phosphorus and manganese, are desirable, and should be retained; but above all, the proper structure to insure safety and wearing qualities, is what is desired in rails. The practice of certain foreign rail specifications of rejecting or accepting 500 tons of rails on the results of the analysis of one rail is untenable.

The recent suggestion of an analysis of drillings from the top part of the web of a certain number of rails from each turn, with a view to discarding segregated rails, is impracticable, as it would interfere with the output of the mill. If segregation is viewed with concern, the engineer can best prevent it by specifying an increased uniform top discard on *all* ingots, a practice, of course, involving an extra cost of the product.

Sample for Chemical Analysis.—The Committee followed the usual practice of requiring a daily report of the carbon determinations of each blow. A complete analysis representing the average of the other constituents to be furnished every 24 hours. These analyses to be made on drillings taken from the test ingots, which is the only practicable way identified samples can be obtained without delaying manufacturing operations. Some specifications also require a manganese on each heat, and others require "a sufficient number of

complete analyses to represent the average steel of each day's work."

Drop Test.—The specification requires this test on every fifth blow, specifies all essential details including the recording of the atmospheric temperature when the test is made. Some engineers, laying great stress on the value of this test, which, even if crude, is a check on brittleness, specify that it shall be made on every blow of steel, and others in addition state that the test should be taken from some designated location, preferably from a rail from the top of one of the ingots. Others leave the selection of the test to the inspector.

A recent important American specification includes the following clause, specifying a maximum deflection under the first blow. "The weight falling from such height as to make a blow of 27,000 foot pounds for 60 lb. rail; 32,000 foot pounds for 70 lb. rail; 40,000 foot pounds for 85 lb. rail, and 49,000 foot pounds for 100 lb. rail, and the deflection produced must not exceed 2 3/4″ inches at the first blow.

Tensile Strength.—The specified tensile strength, elongation, and in some cases contraction of area, met in the majority of foreign rail specifications are unnecessary requirements. The tensile specimen is never representative. If taken from the center of the head it is affected by segregation; if from near the surface the results are apt to be affected by partially welded blow-holes. In no case does it truly represent the rail, much less any lot of rails from which the sample rail was selected.

Dead Weight Test.—Seventy per cent. of the 41 foreign rail specifications reviewed by the writer, specify this test. The loads specified are often within the elastic limit of the steel, so that the deflections are merely factors of the section. The test to be of any value should include a determination of the yield point and by means of still heavier loads, the greatest permanent deflection. The requirements of the dead weight tests contained in foreign rail specifications are met without difficulty by American mills.

Finishing Temperature. — The improvements in rolling recently introduced[1] by which rails are finished at a lower temperature than formerly, will doubtless stimulate the demand for a clause in the standard specification by which the benefits resulting therefrom will be assured. Three methods have been proposed as a check on the finishing

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1 United States Patents Nos. 654,071 and 654,100, filed May 23, 1900.

"The Kennedy-Morrison Rail Finishing Process." *The Iron Age*, Dec. 20, 1900, pp, 16–18, with plate.

Robt. W. Hunt. "Finishing Temperatures for Steel." *Trans. Amer. Inst. Mining Engineers*. February, 1901. Abstract in *The Iron Age*, Feb. 21, 1901, pp. 10–12, and *The Railroad Gazette*, Feb. 22, 1901, pp. 124–5.

W. R. Webster. "The Chemistry and Heat Treatment of Steel Rails." *Trans. Amer. Inst. Mining Engineers*, Feb., 1901. Abstracted in *The Railroad Gazette*, Feb. 22, 1901, p. 124.

"Rail Steel as Affected by Slow Cooling." *Railroad Gazette*, March 8, 1901, p. 169, illustrated also pp. 172–3.

S. S. Martin. "Rail Rolling at Lower Temperatures." *The Iron Age*, Dec. 26, 1901, pp. 4–6, illustrated. *Railroad Gazette*, Jan. 3, 1902, pp. 1–2, ills.

"Rolling Rails at Low Temperature." *Railroad Gazette*, Jan. 24, 1902. pp. 60-61.

temperature. The color of the finished rail, the use of a pyrometer, and the amount of shrinkage which takes place in a rail of standard length from the time it is cut at the hot saws, until it is cooled and straightened. The last is the simplest and most practicable; the amount of shrinkage to insure proper structure in each standard section can be accurately determined by experiment. Recent data has been submitted showing that the shrinkage allowance should be higher when rails are rolled direct from the ingot, instead of from reheated blooms; for although the final finishing temperature is important, the proper structure is also obtained by putting sufficient work on the ingot at a low enough temperature to break up the coarse structure.

Sections.—Unless otherwise specified, the Committee provides that the sections recommended in 1893 by the American Society of Civil Engineers shall be used. In 1899, fully 75 per cent. of all the rails rolled in the United States were the "A. S. C. E. Standards,"[1] a vast improvement over the conditions reported in 1881, by A. L. Holley,[2] when the rail mills had 188 different patterns which were considered as standards, and of these, 119 patterns of 27 different weights per yard were regularly manufactured. The new A. S. C. E. rail committee authorized in July, 1901, will doubtless recommend

[1] In March, 1901, the Rail Committee of American Railway Engineer and Maintenance-of-Way Association reported that 83 railroads out of 127 were using the "A. S. C. E. Standards."

[2] *Transactions of the American Institute of Mining Engineers*, Vol. IX, pp. 360–375.

heavier flanges for their standards due to the recent change in finishing temperatures. The standard specification allows the usual variations in height of $^1/_{64}''$ less, and $^1/_{32}''$ greater than specified height, but provides that a perfect fit of the splice bars shall be maintained. American mill practice is well within these limits.

Finish.—The provisions specified insure rails of workmanlike finish, with square clean ends, free from the burrs occasioned by the saws. Some specifications include, in addition to those mentioned in this paragraph, instructions as to straightening. The rails are to be straightened by pressure, not blows. The gag shall have sufficient bearing surface to prevent indenting the rail. The seat on which the rail rests must be a true plane, and the rail must not have over a certain camber as it leaves the cooling beds and when finished must be free from twists, waves or kinks. These requirements are met in most American mills and would be complied with at the request of the inspector, without being included in the written specification.

Length.—The standard length of 30′ is specified. The Committee should have added the clause "at a temperature of 60° Fahrenheit." Ten per cent. of the order may be 28, 26, or 24 feet. A variation of $\pm$ 1/4″ in length is allowable. The standard length may possibly be changed in future to 33′, which would reduce the number of joints 10 per cent. About 10 per cent. of the mileage of the A. Ry. Engr. and Maint. of Way Asso. have already made 33′ a standard length. It is governed by

the length of the cars which has of late years increased.

The requirements under *weight*, *drilling*, *branding*, and *inspection*, amply cover the best current practice. Second quality or No. 2 rails are carefully defined. The percentage to be accepted is not specified, as it should be arranged between buyer and maker.

SPECIFICATION FOR STEEL SPLICE BARS.

The Committee's specification is more complete and more carefully drawn up than many of the specifications for splice bars issued by the railroads.

The steel may be made either by the Bessemer or open-hearth process, the phosphorus limit being 0.10 per cent. and the manganese 0.30–0.60 per cent. Both carbon and tensile strength were specified, because the latter is seldom called for on each blow or melt of steel rolled into splice bars, the carbon and bending test being considered a sufficient check. The specification, however, provides for one tensile and one bending test specimen from each heat. The chemical analysis is made on drillings from the test ingot.

The importance of having the splice bars accurately fit the rails for which they are intended, was recognized by the Committee's paragraph on finish, which also specifies that a variation in weight of more than 2 1/2 per cent. from that specified will be sufficient cause for rejection.

SPECIFICATION FOR STRUCTURAL STEEL FOR BUILDINGS, AND STRUCTURAL STEEL FOR BRIDGES AND SHIPS.

As these two specifications contain many points in common, they will be discussed jointly. The tabulation, by the Committee, of the numerous existing specifications showed the impossibility of harmonizing all requirements. The prescribed tests adopted for the standard specifications, are those under which the majority of the large tonnage of structural steel is furnished.

Chemical and Physical Tests.—The chemical and physical requirements of the two specifications are compared in Table V.

For steel for buildings the phosphorus was fixed as 0.10 per cent. because Bessemer steel is still used to some extent. The limits given for phosphorus and sulphur for bridge steel, although higher than often specified, are perfectly fair to the consumer. The extra qualities of low carbon steel, 0.02 per cent. lower in phosphorus than above limits, are inappreciable. Low carbon steels of 0.06 per cent. sulphur bend, forge and weld perfectly; a requirement of 0.05 per cent. sulphur is sometimes a hardship on the manufacturer, and is unnecessary as the lower sulphur steel is no better under hot working, nor has it a longer life in service.

The range of 10,000 pounds in tensile strength shown above was chosen not only because it conforms to usual practice, but because it is fair to both interests. Some have advocated a reduction of the range to 8,000 pounds. Others have suggested

TABLE V.

Requirements specified.	Structural steel for				
	Buildings.		Bridges and ships.		
Process of manufacture	Open-hearth or Bessemer.		Open-hearth.		
Phosphorus shall not exceed	0.10 per cent.		0.08% if acid, 0.06% if basic.		
Sulphur shall not exceed	....		0.06% if acid, 0.06% if basic.		
	Rivet steel.	Medium steel.	Rivet steel.	Soft steel.	Medium steel.
Tensile strength, pounds per square inch	50–60,000.	60–70,000.	50–60,000	52–62,000	60–70,000
Yield point, pounds per square inch	½ T. S.	½ T. S.	½ T. S.	½ T. S.	½ T. S.
Elongation, per cent in eight inches not less than	26	22	26	25	22
Cold bending test D = diameter. t = thickness.	180° flat.	D = t.	180° flat.	180° flat.	D = t.

abolishing "soft" and "medium" bridge steel and substituting one class with a tensile strength of 55,000 to 65,000 pounds. Both "soft" and "medium" steel have their uses and should therefore be retained; for the principal members of bridges, medium steel should be specified. There has been some recent discussion as to whether a steel of over 70,000 pounds tensile strength can be safely specified. Doubtless if melted, rolled, and assembled with extra care it could be used with entire safety and would give satisfactory service, but under usual conditions and for the purpose of a standard specification it seemed advisable to place the upper limit at 70,000 pounds.

The permissible modifications in the percentage of elongation for thin and thick material, and for pins, are the same in each specification. In the specification for steel for bridges and ships, an important paragraph giving the requirements of the full sized tests for eye bars is given.

Sheared Bending Tests.—The Committee's two specifications state that the sheared edges of the bending test specimens may be milled or planed. It has recently been claimed that since "soft" steel is generally used without reaming or planing, that the required bending test should be made on specimens having the sheared edges unplaned. While it is true that in testing "soft" steel many bending specimens with unplaned edges will stand the test of "bending cold 180° flat on itself without fracture on the outside of the bent portion," yet some will fail, due to distortion, ragged edges, etc., produced by shearing. The failure of such tests is not

indicative that the material under inspection is brittle.

The same paragraphs appear in each of the two specifications, defining the test specimens for tensile test[1] and for bending test, the number of the specimens and their location. Provision is made for testing annealed material. Yield point is also defined and the location given for the sample for chemical analysis.

Variation in Weight.—Both specifications state that variation in cross section or weight of more than 2 1/2 per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates where permissible variations are given to cover plates whether ordered by weight or by gauge.

Finish, Branding, and Inspection.—The same ample provisions are made in each specification governing the finish, branding, and inspection of the material.

SPECIFICATION FOR OPEN-HEARTH BOILER PLATE AND RIVET STEEL.

Process of Manufacture and Chemical Properties.—As the Committee limits the maker to the open-hearth process, it was necessary to distinguish between acid and basic steel, in specifying the maximum phosphorus and sulphur allowed. The limits specified, amply protect the consumer for

[1] See Figure II and the remarks on the eight-inch tensile test specimen given on pages 22-23.

the majority of purposes for which plate and rivet steel are used. For the comparatively small tonnage of plates sold under lower guarantees in phosphorus and sulphur than those mentioned in § 2, page 96. the maker is justified in asking an extra price as, for example, the American Boiler Makers' Specification. In many instances, steel conforming to the standard specification would be found to give just as satisfactory service as steel of still lower phosphorus and sulphur.

The Committee included limits in manganese and then purposely omitted limits in carbon, thus adhering to their general policy of leaving the percentage of carbon to the maker when the other principal chemical constituents are specified and the physical properties clearly defined. In fire-box steel, for instance, if carbon is specified as well as manganese and tensile strength, it usually limits the maker to furnish either acid or basic steel, for the lower phosphorus and silicon of the basic steel necessitates the presence of more carbon for a specified tensile strength. A standard specification should not place this restriction on the maker.

Physical Properties.—The Committee considered that a subdivision of open-hearth boiler plate and rivet steel into three classes was sufficient, namely, *flange* or *boiler steel*, *fire-box steel*, and *extra soft* or *rivet steel*. Shell steel was abolished. The physical requirements for these three classes are given in § 4, page 97, and § 5 specifies the permissible modifications for thin and thick material. As in the two preceding specifications, the Committee wisely decided to modify the specified elongation,

and adhere to the standard gauged length of eight inches.

Number of Test Specimens.—The Committee requires one tensile test specimen, one cold bending, and one quench bending specimen from each plate as it is rolled, and two of each of these three specimens from each melt of rivet rounds.

Bending Tests.—Each of the three classes of steel is required both before and after quenching, "to bend 180° flat on itself without fracture on the outside of the bent portion." The tests may be milled or planed.[1] The cold bend is a check on brittleness due to finishing at too high a temperature. The quench bend is a check on excess of carbon or other hardening elements.

There is no necessity for a clause in this specification for annealed test specimens, as plates and rivet steel are tested as rolled. Extra heavy boiler plates would be better for annealing, and a clause to this effect could be added by the engineer to cover special requirements.

Homogeneity Test.—For this test, applicable only to fire-box steel, the Committee wisely followed the requirements and the detailed method of making the test, prescribed by the Pennsylvania Railroad, who were the originators of this test which is used to determine the uniformity of the metal; that is, freedom from closed or partially welded blow holes, pipe, or slag.

Sample for Chemical Analysis.—The Committee provided for a check analysis from a tensile speci-

[1] Compare pages 52–53..

men from each melt, and for locomotive fire-box steel, from a tensile specimen from each plate as rolled.

Variation in Weight.—The same permissible allowances in weight are given in this specification as in the two structural steel specifications. It may be possible that this table will need modification to allow for 1/4″ plates over 120″ wide, and plates less than 1/4″ when 65″ or over in width.

Finish, Branding, and Inspection.—The requirements as to finish and inspection are the same as in the two previous specifications discussed. Provision is made under branding, for stamping each plate and coupon or test specimen cut therefrom. Some specifications give detailed instructions for match-marking plates. Rivet steel is to be securely wired in bundles with a metal tag, giving the melt number attached.

Appendix.

Revised Text of the American Standard Specifications for Steel, adopted by the American Section of the International Association for Testing Materials, August 10th, 1901.

Steel Castings.

Process of Manufacture.

1. Steel for castings may be made by the open-hearth, crucible or Bessemer process. Castings to be annealed or unannealed as specified.

Chemical Properties.

ORDINARY CASTINGS.

2. Ordinary castings, those in which no physical requirements are specified, shall not contain over 0.40 per cent. of carbon, nor over 0.08 per cent. of phosphorus.

TESTED CASTINGS.

3. Castings which are subjected to physical test shall not contain over 0.05 per cent. of phosphorus, nor over 0.05 per cent. of sulphur.

Physical Properties.

TENSILE TESTS.

4. Tested castings shall be of three classes: "HARD," "MEDIUM," and "SOFT." The minimum physical qualities required in each class shall be as follows:

	Hard castings	Medium castings	Soft castings
Tensile strength, lbs. per sq. in . .	85,000	70,000	60,000
Yield point, lbs. per sq. in	38,250	31,500	27,000
Elongation, per cent. in two inches	15	18	22
Contraction of area, per cent . . .	20	25	30

DROP TEST.

5. A test to destruction may be substituted for the tensile test, in the case of small or unimportant castings, by selecting three castings from a lot. This test shall show the material to be ductile and free from injurious defects, and suitable for the purposes intended. A lot shall consist of all castings from the same melt or blow, annealed in the same furnace charge.

PERCUSSIVE TEST.

6. Large castings are to be suspended and hammered all over. No cracks, flaws, defects, nor weakness shall appear after such treatment.

BENDING TEST.

7. A specimen one inch by one-half inch ($1'' \times \frac{1}{2}''$) shall bend cold around a diameter of one inch ($1''$) without fracture on outside of bent portion, through an angle of 120° for "SOFT" castings, and of 90° for "MEDIUM" castings.

Test Pieces and Methods of Testing.

TEST SPECIMEN FOR TENSILE TEST.

8. The standard turned test specimen, one-half inch (½″) diameter and two inch (2″) gauged length, shall be used to determine the physical properties specified in paragraph No. 4. It is shown in Figure 1.

NUMBER AND LOCATION OF TENSILE SPECIMENS.

9. The number of standard test specimens shall depend upon the character and importance of the castings. A test piece shall be cut cold from a coupon to be molded and cast on some portion of one or more castings from each melt or blow or from the sink-heads (in case heads of sufficient size are used). The coupon or sink-head must receive the same treatment as the casting or castings, before the specimen is cut out, and before the coupon or sink-head is removed from the casting.

TEST SPECIMEN FOR BENDING.

10. One specimen for bending test one inch by one-half inch (1″ x ½″) shall be cut cold from the coupon or sink-head of the casting or castings as specified in paragraph No. 9. The bending test may be made by pressure, or by blows.

YIELD POINT.

11. The yield point specified in paragraph No. 4 shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

SAMPLE FOR CHEMICAL ANALYSIS.

12. Turnings from the tensile specimen, drillings from the bending specimen, or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in phosphorus and sulphur specified in paragraphs Nos. 2 and 3.

Finish.

13. Castings shall be true to pattern, free from blemishes, flaws or shrinkage cracks. Bearing surfaces shall be solid, and no porosity shall be allowed in positions where the resistance and value of the casting for the purpose intended, will be seriously affected thereby.

Inspection.

14. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

Steel Axles.

Process of Manufacture.

1. Steel for axles shall be made by the open-hearth process.

Chemical Properties.

2. There will be three classes of steel axles which shall conform to the following limits in chemical composition :

	Car, engine truck and tender truck axles. Per cent.	Driving wheel axles. (Carbon steel.) Per cent.	Driving wheel axles. (Nickel steel.) Per cent.
Phosphorus shall not exceed . .	0.06	0.06	0.04
Sulphur shall not exceed	0.06	0.06	0.04
Nickel	. .	. .	3.00-4.00

Physical Properties.

TENSILE TESTS.

3. For car, engine truck, and tender truck axles no tensile test shall be required.

4. The minimum physical qualities required in the two classes of driving wheel axles shall be as follows:

	Driving wheel axles. (Carbon steel.)	Driving wheel axles. (Nickel steel.)
Tensile strength, pounds per sq. in.	80,000	80,000
Yield point, pounds per sq. in.	40,000	50,000
Elongation, per cent. in two inches	18	25
Contraction of area per cent.	..	45

DROP TEST.

5. One axle selected from each melt, when tested by the drop test described in paragraph No. 9, shall stand the number of blows at the height specified in the following table without rupture and without exceeding, as the result of the first blow, the deflection given. Any melt failing to meet these requirements will be rejected.

Diameter of axle at center. Inches.	Number of blows.	Height of drop. Feet.	Deflection. Inches.
4 1/4	5	24	8 1/4
4 3/8	5	26	8 1/4
4 7/16	5	28 1/2	8 1/4
4 5/8	5	31	8
4 3/4	5	34	8
5 3/8	5	43	7
5 7/8	7	43	5 1/2

6. Carbon steel and nickel steel driving wheel axles shall not be subject to the above drop test.

Test Pieces and Methods of Testing.

TEST SPECIMEN FOR TENSILE TEST.

7. The standard turned test specimen one-half inch (½″) diameter and two inch (2″) gauged length, shall be used to determine the physical properties specified in paragraph No. 4. It is shown in Figure 1.

NUMBER AND LOCATION OF TENSILE SPECIMENS.

8. For driving axles one longitudinal test specimen shall be cut from one axle of each melt. The center of this test specimen shall be half way between the center and outside of the axle.

DROP TEST DESCRIBED.

9. The points of supports on which the axle rests during tests must be three feet apart from center to center; the tup must weigh 1,640 pounds; the anvil, which is supported on springs, must weigh 17,500 pounds; it must be free to move in a vertical direction; the springs upon which it rests must be twelve in number, of the kind described on drawing; and the radius of supports and of the striking face on the tup in the direction of the axis of the axle must be five (5) inches. When an axle is tested it must be so placed in the machine that the tup will strike it midway between the ends, and it must be turned over after the first and third blows, and when required, after the fifth blow. To measure the deflection after the first blow prepare a straight edge as long as the axle, by reinforcing it on one side, equally at each end, so that when it is laid on the axle, the reinforced parts will rest on the collars or ends of the axle, and the balance of the straight edge not touch the axle at any place. Next place the axle in position for test, lay the straight edge on it, and measure the distance from the straight edge to the axle at the middle point of the latter. Then after the first blow, place the straight edge on the now bent axle in the same manner as before, and measure the distance from it to that side of the axle next to the straight edge at the point farthest away from the latter. The difference between the two measurements is the deflection. The report of the drop test shall state the atmospheric temperature at the time the tests were made.

YIELD POINT.

10. The yield point specified in paragraph No. 4 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine.

SAMPLE FOR CHEMICAL ANALYSIS.

11. Turnings from the tensile test specimen of driving axles, or drillings taken midway between the center and outside of car, engine, and tender truck axles, or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether the melt is within the limits of chemical composition specified in paragraph No. 2.

Finish.

12. Axles shall conform in sizes, shapes and limiting weights to the requirements given on the order or print sent with it. They shall be made and finished in a workmanlike manner, and shall be free from all injurious cracks, seams or flaws. In centering, sixty (60) degree centers must be used, with clearance given at the point to avoid dulling the shop lathe centers.

Branding.

13. Each axle shall be legibly stamped with the melt number and initials of the maker at the places marked on the print or indicated by the inspector.

Inspection.

14. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

Steel Forgings.

Process of Manufacture.

1. Steel for forgings may be made by the open-hearth, crucible or Bessemer process.

Chemical Properties.

2. There will be four classes of steel forgings which shall conform to the following limits in chemical composition.

	Forgings of soft or low carbon steel.	Forgings of carbon steel not annealed	Forgings of carbon steel, oil tempered or annealed.	Forgings of nickel steel, oil tempered or annealed.
	Per cent.	Per cent.	Per cent.	Per cent.
Phosphorus shall not exceed . . .	0.10	0.06	0.04	0.04
Sulphur shall not exceed	0.10	0.06	0.04	0.04
Nickel	——	——	——	3.00-4.00

Physical Properties.

TENSILE TESTS.

3. The minimum physical qualities required of the different sized forgings of each class shall be as follows:

Tensile strength.	Yield point.	Elongation in 2".	Contraction of area.	
Lbs. per sq. in.		Per cent.		SOFT STEEL OR LOW CARBON STEEL.
58,000	29,000	28	35	For solid or hollow forgings, no diameter or thickness of section to exceed 10".
				CARBON STEEL NOT ANNEALED.
75,000	37,500	18	30	For solid or hollow forgings, no diameter or thickness of section to exceed 10".

Tensile strength.	Elastic limit.	Elongation in 2″.	Contraction of area.	
Lbs. per sq. in.		Per cent.		
				CARBON STEEL ANNEALED.
80,000	40,000	22	35	For solid or hollow forgings, no diameter or thickness of section to exceed 10″.
75,000	37,500	23	35	For solid forgings, no diameter to exceed 20″ or thickness of section 15″.
70,000	35,000	24	30	For solid forgings, over 20″ diameter.
				CARBON STEEL, OIL-TEMPERED.
90,000	55,000	20	45	For solid or hollow forgings, no diameter or thickness of section to exceed 3″.
85,000	50,000	22	45	For solid forgings of rectangular sections not exceeding 6″ in thickness or hollow forgings, the walls of which do not exceed 6″ in thickness.
80,000	45,000	23	40	For solid forgings of rectangular sections not exceeding 10″ in thickness or hollow forgings, the walls of which do not exceed 10″ in thickness.
				NICKEL STEEL ANNEALED.
80,000	50,000	25	45	For solid or hollow forgings, no diameter or thickness of section to exceed 10″.
80,000	45,000	25	45	For solid forgings, no diameter to exceed 20″ or thickness of section 15″.
80,000	45,000	24	40	For solid forgings, over 20″ diameter.
				NICKEL STEEL, OIL-TEMPERED.
95,000	65,000	21	50	For solid or hollow forgings, no diameter or thickness of section to exceed 3″.
90,000	60,000	22	50	For solid forgings of rectangular sections not exceeding 6″ in thickness or hollow forgings, the walls of which do not exceed 6″ in thickness.
85,000	55,000	24	45	For solid forgings of rectangular sections not exceeding 10″ in thickness or hollow forgings, the walls of which do not exceed 10″ in thickness.

BENDING TEST.

4. A specimen one inch by one-half inch (1″x½″) shall bend cold 180° without fracture on outside of bent portion, as follows:

Around a diameter of ½″, for forgings of soft steel,

Around a diameter of 1 ½″, for forgings of carbon steel not annealed,

Around a diameter of 1 ½″, for forgings of carbon steel, if 20″ in diameter or over,

Around a diameter of 1″, for forgings of carbon steel annealed, if under 20″ diameter,

Around a diameter of 1″ for forgings of carbon steel oil-tempered,

Around a diameter of ½″, for forgings of nickel steel annealed,

Around a diameter of 1″, for forgings of nickel steel oil-tempered.

Test Pieces and Methods of Testing.

TEST SPECIMEN FOR TENSILE TEST.

5. The standard turned test specimen, one-half inch (½″) diameter and (2″) gauged length, shall be used to determine the physical properties specified in paragraph No. 3. It is shown in Figure 1.

NUMBER AND LOCATION OF TENSILE SPECIMENS.

6. The number and location of test specimens to be taken from a melt, blow, or a forging shall depend upon its character and importance and must therefore be regulated by individual cases. The test specimens shall be cut cold from the forging or full-sized prolongation of same parallel to the axis of the forging and half way between the center and outside, the specimens to be longitudinal, *i. e.*, the length of the specimen to correspond with the direction in which the metal is most drawn out or worked. When forgings have large ends or collars, the test specimens shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged or bored, the specimen shall be taken within the finished section prolonged, half way between the inner and outer surface of the wall of the forging.

TEST SPECIMEN FOR BENDING.

7. The specimen for bending test one inch by one-half inch (1"x½") shall be cut as specified in paragraph No. 6. The bending test may be made by pressure or by blows.

YIELD POINT.

8. The yield point specified in paragraph No. 3 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine.

ELASTIC LIMIT.

9. The elastic limit specified in paragraph No. 3 shall be determined by means of an extensometer, which is to be attached to the test specimen in such manner as to show the change in rate of extension under uniform rate of loading, and will be taken at that point where the proportionality changes.

SAMPLE FOR CHEMICAL ANALYSIS.

10. Turnings from the tensile specimen or drillings from the bending specimen or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in chemical composition specified in paragraph No. 2.

Finish.

11. Forgings shall be free from cracks, flaws, seams, or other injurious imperfections, and shall conform to dimensions shown on drawings furnished by the purchaser, and be made and finished in a workmanlike manner.

Inspection.

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

Steel Tires.

Process of Manufacture.

1. Steel for tires may be made by either the open-hearth or crucible process.

Chemical Properties.

2. There will be three classes of steel tires which shall conform to the following limits in chemical composition :

	Passenger engines. Per cent.	Freight engine and car wheels. Per cent.	Switching engines. Per cent.
Manganese shall not exceed . . .	0.80	0.80	0.80
Silicon shall not be less than . .	0.20	0.20	0.20
Phosphorus shall not exceed . . .	0.05	0.05	0.05
Sulphur shall not exceed	0.05	0.05	0.05

Physical Properties.

TENSILE TESTS.

3. The minimum physical qualities required in each of the three classes of steel tires shall be as follows :

	Passenger engines.	Freight engine and car wheels.	Switching engines.
Tensile strength, pounds per sq. in.	100,000	110,000	120,000
Elongation, per cent. in two inches	12	10	8

DROP TEST.

4. In the event of the contract calling for a drop test, a test tire from each melt will be furnished at the purchaser's expense, provided it meets the requirements. This test tire shall stand the drop test described in paragraph No. 7, without breaking or cracking, and shall show a minimum deflection equal to $D^2 \div (40T^2 + 2D)$, the letter "D" being internal diameter and the letter "T" thickness of tire at center of tread.

Test Pieces and Methods of Testing.

TEST SPECIMEN FOR TENSILE TESTS.

5. The standard turned test specimen, one-half inch (1/2″) diameter and two inch (2″) gauged length, shall be used to determine the physical properties specified in paragraph No. 3. It is shown in Figure 1.

LOCATION OF TENSILE SPECIMENS.

6. When the drop test is specified, this test specimen shall be cut cold from the tested tire at the point least affected by the drop test. If the diameter of the tire is such that the whole circumference of the tire is seriously affected by the drop test, or if no drop test is required, the test specimen shall be forged from a test ingot cast when pouring the melt, the test ingot receiving, as nearly as possible, the same proportion of reduction as the ingots from which the tires are made.

DROP TEST DESCRIBED.

7. The test tire shall be placed vertically under the drop in a running position on a solid foundation of at least ten tons in weight and subjected to successive blows from a tup weighing 2240 pounds, falling from increasing heights until the required deflection is obtained.

SAMPLE FOR CHEMICAL ANALYSIS.

8. Turnings from the tensile specimen, or drillings from the small test ingot, or turnings from the tire if preferred by the inspector, shall be used to determine whether the melt is within the limits of chemical composition specified in paragraph No. 2.

Finish.

9. All tires shall be free from cracks, flaws, or other injurious imperfections, and shall conform to dimensions shown on drawings furnished by the purchaser.

Branding.

10. Tires shall be stamped with the maker's brand and number in such a manner that each individual tire may be identified.

Inspection.

11. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

Steel Rails.

Process of Manufacture.

1. (*a*). Steel may be made by the Bessemer or open-hearth process.

(*b*). The entire process of manufacture and testing shall be in accordance with the best standard current practice, and special care shall be taken to conform to the following instructions.

(*c*). Ingots shall be kept in a vertical position in pit heating furnaces.

(*d*). No bled ingots shall be used.

(*e*). Sufficient material shall be discarded from the top of the ingots to insure sound rails.

Chemical Properties.

2. Rails of the various weights per yard specified below shall conform to the following limits in chemical composition :

	50 to 59 + pounds. Per cent.	60 to 69 + pounds. Per cent.	70 to 79 + pounds. Per cent.	80 to 89 + pounds. Per cent.	90 to 100 pounds. Per cent.
Carbon	0.35–0.45	0.38–0.48	0.40–0.50	0.43–0.53	0.45–0.55
Phosphorus shall not exceed	0.10	0.10	0.10	0.10	0.10
Silicon shall not exceed .	0.20	0.20	0.20	0.20	0.20
Manganese . .	0.70–1.00	0.70–1.00	0.75–1.05	0.80–1.10	0.80–1.10

Physical Properties.

DROP TEST.

3. One drop test shall be made on a piece of rail not more than six feet long, selected from every fifth blow of steel. The rail shall be placed head upwards on the supports and the various sections shall be subjected to the following impact tests :

Weight of rail. Pounds per yard.	Height of drop. Feet.
45 to and including 55	15
More than 55 " 65	16
" 65 " 75	17
" 75 " 85	18
" 85 " 100	19

If any rail break when subjected to the drop test, two additional tests will be made of other rails from the same blow of steel, and if either of these latter tests fail all the rails of the blow which they represent will be rejected, but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted. If the rails from the tested blow shall be rejected for failure to meet the requirements of the drop test as above specified, two other rails will be subjected to the same tests, one from the blow next preceding, and one from the blow next succeeding the rejected blow. In case the first test taken from the preceding or succeeding blow shall fail, two additional tests shall be taken from the same blow of steel, the acceptance or rejection of which shall also be determined as specified above, and if the rails of the preceding or succeeding blow shall be rejected, similar tests may be taken from the previous or following blows, as the case may be, until the entire group of five blows is tested, if necessary.

The acceptance or rejection of all the rails from any blow will depend upon the result of the tests thereof.

Test Pieces and Methods of Testing.

DROP TESTING MACHINE.

4. The drop test machine shall have a tup of two thousand (2000) pounds weight, the striking face of which shall have a radius of not more than five inches (5″), and the test rail shall be placed head upwards on solid supports three feet (3′) apart. The anvil block shall weigh at least twenty thou-

sand (20,000) pounds, and the supports shall be a part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the tests were made.

SAMPLE FOR CHEMICAL ANALYSIS.

5. The manufacturer shall furnish the inspector, daily, with carbon determinations of each blow, and a complete chemical analysis every twenty-four hours, representing the average of the other elements contained in the steel. These analyses shall be made on drillings taken from a small test ingot.

Finish.

SECTION.

6. Unless otherwise specified, the section of rail shall be the American Standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with paragraph No. 7, relative to specified weight. A variation in height of one sixty-fourth of an inch (1/64″) less and one thirty-second of an inch (1/32″) greater than the specified height will be permitted. A perfect fit of the splice bars, however, shall be maintained at all times.

WEIGHT.

7. The weight of the rails shall be maintained as nearly as possible, after complying with paragraph No. 6, to that specified in contract. A variation of one-half of one per cent. (1/2 %) for an entire order will be allowed. Rails shall be accepted and paid for according to actual weights.

LENGTH.

8. The standard length of rails shall be thirty feet (30′). Ten per cent. (10%) of the entire order will be accepted in shorter lengths, varying by even feet down to twenty-four feet (24′). A variation of one-fourth of an inch (1/4″) in length from that specified will be allowed.

DRILLING.

9. Circular holes for splice bars shall be drilled in accordance with the specifications of the purchaser. The holes shall accurately conform to the drawing and dimensions furnished in every respect, and must be free from burrs.

FINISH.

10. Rails shall be straightened while cold, smooth on head, sawed square at ends, and, prior to shipment, shall have the burr, occasioned by the saw cutting, removed, and the ends made clean. Number 1 rails shall be free from injurious defects and flaws of all kinds.

Branding.

11. The name of the maker, the month and year of manufacture, shall be rolled in raised letters on the side of the web, and the number of the blow shall be stamped on each rail.

Inspection.

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

No. 2 Rails.

13. Rails that possess any injurious physical defects, or which for any other cause are not suitable for first quality, or No. 1 rails, shall be considered as number 2 rails, provided, however, that rails which contain any physical defects which seriously impair their strength shall be rejected. The ends of all number 2 rails shall be painted in order to distinguish them.

Steel Splice Bars.

Process of Manufacture.

1. Steel for splice bars may be made by the Bessemer or open-hearth process.

Chemical Properties.

2. Steel for splice bars shall conform to the following limits in chemical composition :

	Per cent.
Carbon shall not exceed	0.15
Phosphorus shall not exceed	0.10
Manganese	0.30 to 0.60

Physical Properties.

TENSILE TESTS.

3. Splice bar steel shall conform to the following physical qualities :

Tensile strength, pounds per sq. in. . . .	54,000 to 64,000
Yield point, pounds per sq. in.	32,000
Elongation, per cent. in eight inches shall not be less than	25

BENDING TESTS.

4. (*a*). A test specimen cut from the head of the splice bar shall bend 180° flat on itself without fracture on the outside of the bent portion.

(*b*). If preferred the bending tests may be made on an unpunched splice bar, which, if necessary, shall be first flattened, and shall then be bent 180° flat on itself without fracture on the outside of the bent portion.

Test Pieces and Methods of Testing.

TEST SPECIMEN FOR TENSILE TEST.

5. A test specimen of eight inch (8″) gauged length, cut from the head of the splice bar, shall be used to determine the physical properties specified in paragraph No. 3.

NUMBER OF TENSILE TESTS.

6. One tensile test specimen shall be taken from the rolled splice bars of each blow or melt, but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

TEST SPECIMEN FOR BENDING.

7. One test specimen cut from the head of the splice bar shall be taken from a rolled bar of each blow or melt, or if preferred the bending test may be made on an unpunched splice bar, which, if necessary, shall be flattened before testing. The bending test may be made by pressure or by blows.

YIELD POINT.

8. For the purposes of this specification, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

SAMPLE FOR CHEMICAL ANALYSIS.

9. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot.

Finish.

10. All splice bars shall be smoothly rolled and true to templet. The bars shall be sheared accurately to length and free from fins and cracks, and shall perfectly fit the rails for which they are intended. The punching and notching shall accurately conform in every respect to the drawing and dimensions furnished. A variation in weight of more than 2 1/2 per cent. from that specified will be sufficient cause for rejection.

Branding.

11. The name of the maker and the year of manufacture shall be rolled in raised letters on the side of the splice bar.

Inspection.

12. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer, to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

Structural Steel for Buildings.

Process of Manufacture.

1. Steel may be made by either the open-hearth or Bessemer process.

Chemical Properties.

2. Each of the two classes of structural steel for buildings shall not contain more than 0.10 per cent. of phosphorus.

Physical Properties.

CLASSES.

3. There shall be two classes of structural steel for buildings, namely: RIVET STEEL and MEDIUM STEEL which shall conform to the following physical qualities:

TENSILE TESTS.

4.

	Rivet steel.	Medium steel.
Tensile strength, lbs. per sq. in.	50,000–60,000	60,000–70,000
Yield point, in lbs. per sq. in. shall not be less than . . .	1/2 T. S.	1/2 T. S.
Elongation, per cent. in eight in. shall not be less than . .	26	22

MODIFICATIONS IN ELONGATION FOR THIN AND THICK MATERIAL.

5. For material less than five-sixteenths inch (5/16″), and more than three-fourths inch (3/4″) in thickness, the following modifications shall be made in the requirements for elongation :

(*a*). For each increase of one-eighth inch (1/8″) in thickness above three-fourths inch (3/4″), a deduction of one per cent. (1 per cent.) shall be made from the specified elongation.

(*b*). For each decrease of one-sixteenth inch (1/16″) in thickness below five-sixteenths inch (5/16″), a deduction of two and one-half per cent. (2 1/2 %) shall be made from the specified elongation.

(*c*). For pins the required elongation shall be five per cent. (5 %) less than that specified in paragraph No. 4, as determined on a test specimen, the center of which shall be one inch (1″) from the surface.

BENDING TESTS.

6. The two classes of structural steel for buildings shall conform to the following bending tests ; and for this purpose the test specimen shall be one and one-half inches (1 1/2″) wide, if possible, and for all material three-fourths inch (3/4″) or less in thickness the test specimen shall be of the same thickness as that of the finished material from which it is cut, but for material more than three-fourths inch (3/4″) thick the bending test specimen may be one-half inch (1/2″) thick :

Rivet rounds shall be tested of full size as rolled.

(*d.*) Rivet steel shall bend cold 180° flat on itself without fracture on the outside of the bent portion.

(*e.*) Medium steel shall bend cold 180° around a diameter equal to the thickness of the specimen tested, without fracture on the outside of the bent portion.

Test Pieces and Methods of Testing.

TEST SPECIMEN FOR TENSILE TESTS.

7. The standard test specimen of eight inch (8″) gauged length, shall be used to determine the physical properties specified in paragraphs Nos. 4 and 5. The standard shape of the test specimen for sheared plates shall be as shown by Figure II. For other material the test specimen may be the same as for sheared plates, or it may be planed or turned parallel throughout its entire length and in all cases where possible, two opposite sides of the test specimen shall be the rolled surfaces. Rivet rounds and small rolled bars shall be tested of full size as rolled.

NUMBER OF TENSILE TESTS.

8. One tensile test specimen shall be taken from the finished material of each melt or blow, but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

TEST SPECIMEN FOR BENDING.

9. One test specimen for bending shall be taken from the finished material of each melt or blow as it comes from the rolls and for material three-fourths inch (3/4") and less in thickness this specimen shall have the natural rolled surface on two opposite sides. The bending test specimen shall be one and one-half inches (1 1/2") wide, if possible, and for material more than three-fourths inch (3/4") thick the bending test specimen may be one-half inch (1/2") thick. The sheared edges of bending test specimens may be milled or planed.

Rivet rounds shall be tested of full size as rolled.

(*f*). The bending test may be made by pressure or by blows.

ANNEALED TEST SPECIMENS.

10. Material which is to be used without annealing or further treatment shall be tested for tensile strength in the condition in which it comes from the rolls. Where it is impracticable to secure a test specimen from material which has been annealed or otherwise treated, a full-sized section of tensile test specimen length, shall be similarly treated before cutting the tensile test specimen therefrom.

YIELD POINT.

11. For the purposes of this specification, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

SAMPLE FOR CHEMICAL ANALYSIS.

12. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot.

Variation in Weight.

13. The variation in cross section or weight of more than 2 1/2 per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(*g*). Plates 12 1/2 pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than 2 1/2 per cent. variation above or 2 1/2 per cent. below the theoretical weight. When 100 inches wide and over, 5 per cent. above or 5 per cent. below the theoretical weight.

(*h*). Plates under 12 1/2 pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, 2 1/2 per cent. above or 2 1/2 per cent. below the theoretical weight. 75 inches wide up to 100 inches wide, 5 per cent. above or 3 per cent. below the theoretical weight. When 100 inches wide and over, 10 per cent. above or 3 per cent below the theoretical weight.

* * * *

(*i*). For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

Table of Allowances for Overweight for Rectangular Plates when Ordered to Gauge.

Plates will be considered up to gauge if measuring not over 1/100 inch less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

Plates 1/4 Inch and Over in Thickness.

Thickness of plate. Inch.	Width of Plate.		
	Up to 75 inches. Per cent.	75 to 100 inches. Percent.	Over 100 inches. Per cent.
1/4	10	14	18
5/16	8	12	16
3/8	7	10	13
7/16	6	8	10
1/2	5	7	9
9/16	4 1/2	6 1/2	8 1/2
5/8	4	6	8
over 5/8	3 1/2	5	6 1/2

Plates under 1/4 Inch in Thickness.

Thickness of Plate. Inch.	Width of Plate.	
	Up to 50 inches. Per cent.	50 inches and above. Per cent.
1/8 up to 5/32	10	15
5/32 " 3/16	8 1/2	12 1/2
3/16 " 1/4	7	10

Finish.

14. Finished material must be free from injurious seams, flaws or cracks, and have a workmanlike finish.

Branding.

15. Every finished piece of steel shall be stamped with the melt or blow number, except that small pieces may be shipped in bundles securely wired together with the melt or blow number on a metal tag attached.

Inspection.

16. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

Structural Steel for Bridges and Ships.

Process of Manufacture.

1. Steel shall be made by the open-hearth process.

Chemical Properties.

2. Each of the three classes of structural steel for bridges and ships shall conform to the following limits in chemical composition:

	Steel made by the acid process. Per cent.	Steel made by the basic process. Per cent.
Phosphorus shall not exceed	0.08	0.06
Sulphur shall not exceed . .	0.06	0.06

Physical Properties.

CLASSES.

3. There shall be three classes of structural steel for bridges and ships, namely: RIVET STEEL, SOFT STEEL, and MEDIUM STEEL, which shall conform to the following physical qualities:

TENSILE TESTS.

4.

	Rivet steel.	Soft steel.	Medium steel.
Tensile strength, pounds per sq. in.	50,000-60,000	52,000-62,000	60,000-70,000
Yield point, in pounds per sq. in., shall not be less than	1/2 T. S.	1/2 T. S.	1/2 T S.
Elongation per cent. in eight inches shall not be less than . .	26	25	22

MODIFICATIONS IN ELONGATION FOR THIN AND THICK MATERIAL.

5. For material less than five-sixteenths inch (5/16″), and more than three-fourths inch (3/4″) in thickness, the following modifications shall be made in the requirements for elongation :

(*a*). For each increase of one-eighth inch (1/8″) in thickness above three-fourths inch (3/4″), a deduction of one per cent. (1 %) shall be made from the specified elongation.

(*b*). For each decrease of one-sixteenth inch (1/16″) in thickness below five-sixteenths inch (5/16″), a deduction of two and one-half per cent. (2 1/2 %) shall be made from the specified elongation.

(*c*). For pins made from any of the three classes of steel, the required elongation shall be five per cent. (5%) less than that specified in paragraph No. 4, as determined on a test specimen the center of which shall be one inch (1″) from the surface.

TENSILE TESTS OF EYE-BARS.

6. Eye-bars shall be of medium steel. Full-sized tests shall show 12 1/2 per cent. elongation in fifteen feet of the body of the eye-bar, and the tensile strength shall not be less than 55,000 pounds per square inch. Eye-bars shall be required to break in the body, but should an eye-bar break in the head, and show twelve and one-half per cent. (12 1/2 %) elongation in fifteen feet and the tensile strength specified, it shall not be cause for rejection, provided that not more than one-third (1/3) of the total number of eye-bars tested break in the head.

BENDING TESTS.

7. The three classes of structural steel for bridges and ships shall conform to the following bending tests; and for this purpose the test specimen shall be one and one-half inches wide, if possible, and for all material three-fourths inch (3/4″) or less in thickness the test specimen shall be of the same thickness as that of the finished material from which it is cut, but for material more than three-fourths inch (3/4″) thick the bending test specimen may be one-half inch (1/2″) thick:

Rivet rounds shall be tested of full size as rolled.

(*d*). Rivet steel shall bend cold 180° flat on itself without fracture on the outside of the bent portion.

(*e*). Soft steel shall bend cold 180° flat on itself without fracture on the outside of the bent portion.

(*f*). Medium steel shall bend cold 180° around a diameter equal to the thickness of the specimen tested, without fracture on the outside of the bent portion.

Test Pieces and Methods of Testing.

TEST SPECIMEN FOR TENSILE TEST.

8. The standard test specimen of eight inch (8″) gauged length, shall be used to determine the physical properties specified in paragraphs Nos. 4 and 5. The standard shape of the test specimen for sheared plates shall be as shown in Figure II.

For other material the test specimen may be the same as for sheared plates, or it may be planed or turned parallel throughout its entire length and in all cases where possible, two opposite sides of the test specimens shall be the rolled surfaces. Rivet rounds and small rolled bars shall be tested of full size as rolled.

NUMBER OF TENSILE TESTS.

9. One tensile test specimen shall be taken from the finished material of each melt, but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

TEST SPECIMENS FOR BENDING.

10. One test specimen for bending shall be taken from the finished material of each melt as it comes from the rolls, and for material three-fourths inch (3/4″) and less in thickness this specimen shall have the natural rolled surface on two opposite sides. The bending test specimen shall be one and one-half inches (1 1/2″) wide, if possible, and for

material more than three-fourths inch (3/4″) thick the bending test specimen may be one-half inch (1/2″) thick. The sheared edges of bending test specimens may be milled or planed.

(*g*). The bending test may be made by pressure or by blows.

ANNEALED TEST SPECIMENS.

11. Material which is to be used without annealing or further treatment shall be tested for tensile strength in the condition in which it comes from the rolls. Where it is impracticable to secure a test specimen from material which has been annealed or otherwise treated, a full-sized section of tensile test specimen length, shall be similarly treated before cutting the tensile test specimen therefrom.

YIELD POINT.

12. For the purpose of this specification, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

SAMPLE FOR CHEMICAL ANALYSIS.

13. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot.

Variation in Weight.

14. The variation in cross section or weight of more than 2 1/2 per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations :

(*h*). Plates 12 1/2 pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than 2 1/2 per cent. variation above or 2 1/2 per cent. below the theoretical weight. When 100 inches wide and over, 5 per cent. above or 5 per cent. below the theoretical weight.

(*i*). Plates under 12 1/2 pounds per square foot, when ordered to weight, shall not average a greater variation than the following :

Up to 75 inches wide, 2 1/2 per cent. above or 2 1/2 per cent. below the theoretical weight. 75 inches wide up to 100 inches wide, 5 per cent. above or 3 per cent. below the theoretical weight. When 100 inches wide and over, 10 per cent. above or 3 per cent. below the theoretical weight.

*   *   *   *

(*j*). For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table :

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over 1/100 inch less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

PLATE 1/4 INCH AND OVER IN THICKNESS.

Thickness of plate. Inch.	Width of plate. Up to 75 inches. Per cent.	75 to 100 inches. Per cent.	Over 100 inches Per cent.
1/4	10	14	18
5/16	8	12	16
3/8	7	10	13
7/16	6	8	10
1/2	5	7	9
9/16	4 1/2	6 1/2	8 1/2
5/8	4	6	8
Over 5/8	3 1/2	5	6 1/2

PLATES UNDER 1/4 INCH IN THICKNESS.

Thickness of plate. Inch.	Width of plate. Up to 50 inches. Per cent.	50 inches and above. Per cent.
1/8 up to 5/32	10	15
5/32 " 3/16	8 1/2	12 1/2
3/16 " 1/4	7	10

Finish.

15. Finished material must be free from injurious seams, flaws, or cracks, and have a workmanlike finish.

Branding.

16. Every finished piece of steel shall be stamped with the melt number, and steel for pins shall have the melt number stamped on the ends. Rivets and lacing steel, and small pieces for pin plates and stiffeners, may be shipped in bundles, securely wired together, with the melt number on a metal tag attached.

Inspection.

17. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

Open-Hearth Boiler Plate and Rivet Steel.

Process of Manufacture.

1. Steel shall be made by the open-hearth process.

Chemical Properties.

2. There shall be three classes of open-hearth boiler plate and rivet steel; namely, FLANGE OR BOILER STEEL, FIRE BOX STEEL, and EXTRA SOFT STEEL, which shall conform to the following limits in chemical composition:

	Flange or boiler steel. Per cent.	Fire box steel. Per cent.	Extra soft steel. Per cent.
Phosphorus shall not exceed	Acid 0.06 Basic 0.04	Acid 0.04 Basic 0.03	0.04
Sulphur shall not exceed	0.05	0.04	0.04
Manganese	0.30 to 0.60	0.30 to 0.50	0.30 to 0.50

BOILER RIVET STEEL.

3. Steel for boiler rivets shall be of the EXTRA SOFT class, as specified in paragraphs Nos. 2 and 4.

Physical Properties.

4. The three classes of open-hearth boiler plate and rivet steel, namely, FLANGE OR BOILER STEEL, FIRE BOX STEEL, and EXTRA SOFT STEEL, shall conform to the following physical qualities:

TENSILE TESTS.

	Flange or boiler steel.	Fire box steel.	Extra soft steel.
Tensile strength, pounds per sq. in.	55,000–65,000	52,000–62,000	45,000–55,000
Yield point, in pounds per sq. in. shall not be less than	1/2 T. S.	1/2 T. S.	1/2 T. S.
Elongation, per cent. in eight inches shall not be less than . . .	25	26	28

MODIFICATIONS IN ELONGATION FOR THIN AND THICK MATERIAL.

5. For material less than five-sixteenths inch (5/16″), and more than three-fourths inch (3/4″) in thickness, the following modifications shall be made in the requirements for elongation:

(*a*). For each increase of one-eighth inch (1/8″) in thickness above three-fourths inch (3/4″), a deduction of one per cent. (1 %) shall be made from the specified elongation.

(*b*). For each decrease of one-sixteenth inch (1/16″) in thickness below five-sixteenths inch (5/16″), a deduction of two and one-half per cent. (2 1/2 %) shall be made from the specified elongation.

BENDING TESTS.

6. The three classes of open-hearth boiler plate and rivet steel shall conform to the following bending tests; and for this purpose the test specimen shall be one and one-half inches (1 1/2") wide, if possible, and for all material three-fourths inch (3/4") or less in thickness the test specimen shall be of the same thickness as that of the finished material from which it is cut; but for material more than three-fourths inch (3/4") thick, the bending test specimen may be one-half inch (1/2") thick:

Rivet rounds shall be tested of full size as rolled.

(*c*). Test specimens cut from the rolled material as specified above, shall be subjected to a cold bending test, and also to a quenched bending test. The cold bending test shall be made on the material in the condition in which it is to be used, and prior to the quenched bending test, the specimen shall be heated to a light cherry-red as seen in the dark and quenched in water, the temperature of which is between 80° and 90° Fahrenheit.

(*d*). Flange or boiler steel, fire-box steel, and rivet steel, both before and after quenching, shall bend cold one hundred and eighty degrees (180°) flat on itself without fracture on the outside of the bent portion.

HOMOGENEITY TESTS.

7. For fire-box steel a sample taken from a broken tensile test specimen, shall not show any single seam or cavity more than one-fourth inch (1/4") long in either of the three fractures obtained on the test for homogeneity, as described below in paragraph 12.

Test Pieces and Methods of Testing.

TEST SPECIMEN FOR TENSILE TEST.

8. The standard test specimen of eight inch (8″) gauged length, shall be used to determine the physical properties specified in paragraphs Nos. 4 and 5. The standard shape of the test specimen for sheared plates shall be as shown in Figure II.

For other material the test specimen may be the same as for sheared plates, or it may be planed or turned parallel throughout its entire length and in all cases where possible, two opposite sides of the test specimens shall be the rolled surfaces. Rivet rounds and small rolled bars shall be tested of full size as rolled.

NUMBER OF TENSILE TESTS.

9. One tensile test specimen will be furnished from each plate as it is rolled, and two tensile test specimens will be furnished from each melt of rivet rounds. In case any one of these develops flaws or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

TEST SPECIMENS FOR BENDING.

10. For material three-fourths inch (3/4″) or less in thickness, the bending test specimen shall have the natural rolled surface on two opposite sides. The bending test specimens cut from plates shall be

one and one-half inches (1 1/2″) wide and for material more than three-fourths inch (3/4″) thick the bending test specimens may be one-half inch (1/2″) thick. The sheared edges of bending test specimens may be milled or planed. The bending test specimens for rivet rounds shall be of full size as rolled. The bending test may be made by pressure or by blows.

NUMBER OF BENDING TESTS.

11. One cold bending specimen and one quenched bending specimen will be furnished from each plate as it is rolled. Two cold bending specimens and two quenched bending specimens will be furnished from each melt of rivet rounds. The homogeneity test for fire-box steel shall be made on one of the broken tensile test specimens.

HOMOGENEITY TESTS FOR FIRE-BOX STEEL.

12. The homogeneity test for fire box steel is made as follows: A portion of the broken tensile test specimen is either nicked with a chisel or grooved on a machine, transversely about a sixteenth of an inch (1/16″) deep, in three places about two inches (2″) apart. The first groove should be made on one side, two inches (2″) from the square end of the specimen; the second, two inches (2″) from it on the opposite side; and the third, two inches (2″) from the last, and on the opposite side from it. The test specimen is then put in a vise, with the first groove about a quarter of an inch (1/4″) above the jaws, care being taken to hold it firmly. The projecting end of the test specimen

is then broken off by means of a hammer, a number of light blows being used, and the bending being away from the groove. The specimen is broken at the other two grooves in the same way. The object of this treatment is to open and render visible to the eye any seams due to failure to weld up, or to foreign interposed matter, or cavities due to gas bubbles in the ingot. After rupture, one side of each fracture is examined, a pocket lens being used if necessary, and the length of the seams and cavities is determined.

YIELD POINT.

13. For the purposes of this specification, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

SAMPLE FOR CHEMICAL ANALYSIS.

14. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot. An additional check analysis may be made from a tensile specimen of each melt used on an order, other than in locomotive fire-box steel. In the case of locomotive fire-box steel a check analysis may be made from the tensile specimen from each plate as rolled.

Variation in Weight.

15. The variation in cross section or weight of more than 2 1/2 per cent from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(*e*). Plates 12 1/2 pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than 2 1/2 per cent. variation above or 2 1/2 per cent. below the theoretical weight. When 100 inches wide and over, 5 per cent. above or 5 per cent. below the theoretical weight.

(*f*). Plates under 12 1/2 pounds per square foot, when ordered to weight, shall not average a greater variation than the following :

Up to 75 inches wide, 2 1/2 per cent. above or 2 1/2 per cent. below the theoretical weight. 75 inches wide up to 100 inches wide, 5 per cent. above or 3 per cent. below the theoretical weight. When 100 inches wide and over, 10 per cent. above or 3 per cent. below the theoretical weight.

* * * *

(*g*). For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table :

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over 1/100 inch less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

PLATES 1/4 INCH AND OVER IN THICKNESS.

Thickness of plate. Inch.	Width of plate. Up to 75 inches. Per cent.	75 to 100 inches. Per cent.	Over 100 inches Per cent.
1/4	10	14	18
5/16	8	12	16
3/8	7	10	13
7/16	6	8	10
1/2	5	7	9
9/16	4 1/2	6 1/2	8 1/2
5/8	4	6	8
Over 5/8	3 1/2	5	6 1/2

PLATES UNDER 1/4 INCH IN THICKNESS.

Thickness of plate. Inch.	Width of plate.	
	Up to 50 inches. Per cent.	50 inches and above. Per cent.
1/8 up to 5/32	10	15
5/32 " 3/16	8 1/2	12 1/2
3/16 " 1/4	7	10

Finish.

16. All finished material shall be free from injurious surface defects and laminations, and must have a workmanlike finish.

Branding.

17. Every finished piece of steel shall be stamped with the melt number, and each plate, and the coupon or test specimen cut from it, shall be stamped with a separate identifying mark or number. Rivet steel may be shipped in bundles securely wired together with the melt number on a metal tag attached.

Inspection.

18. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.